Compliant-Leg Lander vs. Fixed-Leg Lander Concept: an analytical analysis

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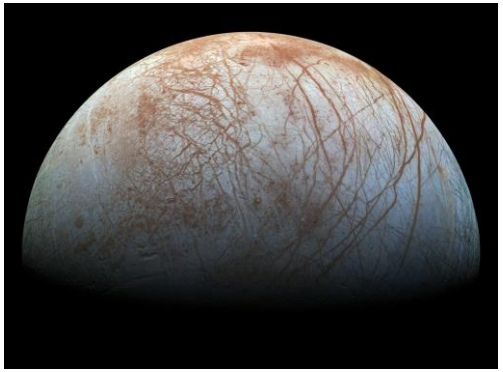
Outline



- Europa Lander Mission Concept
  - *Opportunity and Challenges*
- Evolution of Concept Lander Designs
  - *Early Concept of Fixed-Leg Lander*
  - *Compliant-leg Lander on challenging terrains*
- Case Studies
  - *Fixed-Leg vs. Compliant-Leg Concept Landers*
- Summary

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Europa Lander Mission Concept

A NASA Lander for Jupiter's Icy Moon, Europa

- Provide direct measurement of surface materials along with a geophysical and geological understanding at a local scale
- Search for evidence of life on Europa
- Assess the habitability of Europa by directly analyzing material from the surface
- Characterize the surface and subsurface for future missions

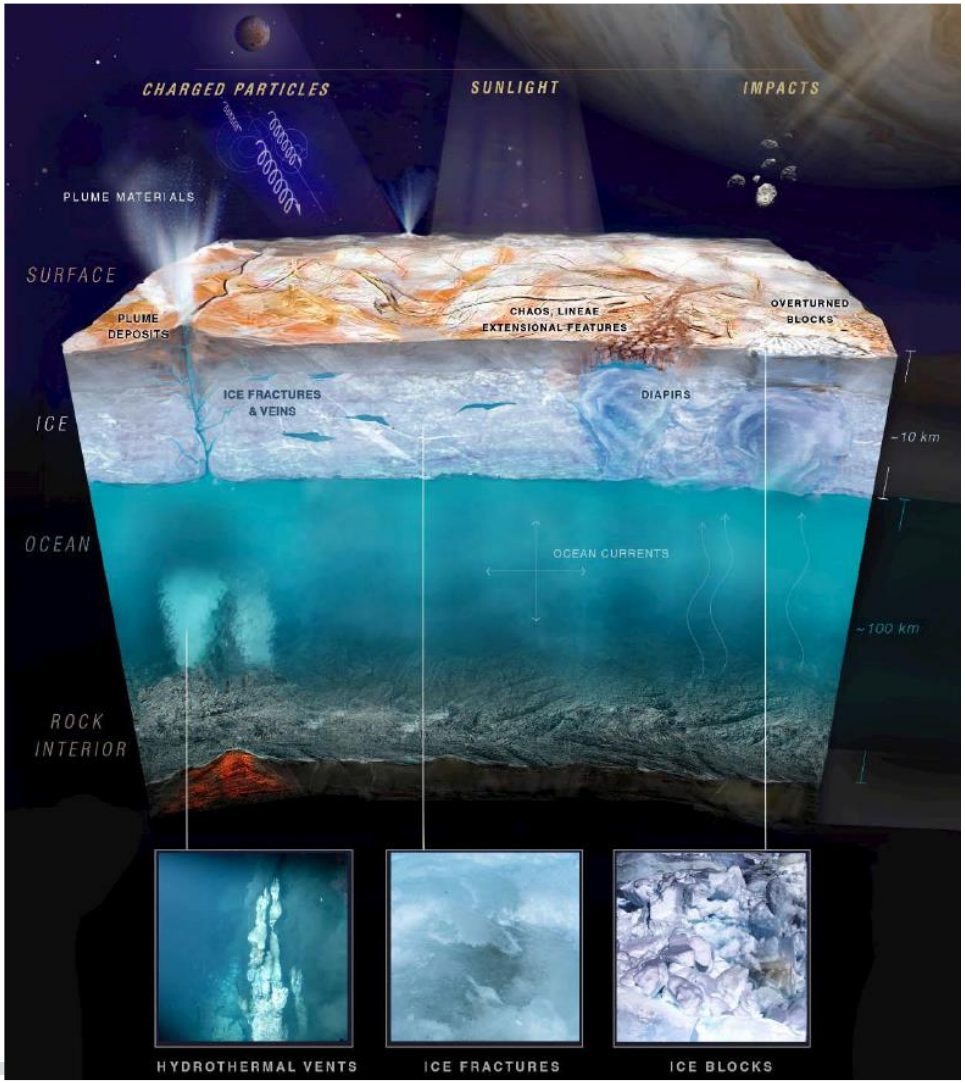

Fig 3.5: NASA Europa Study 2016 Report
Europa Lander Mission

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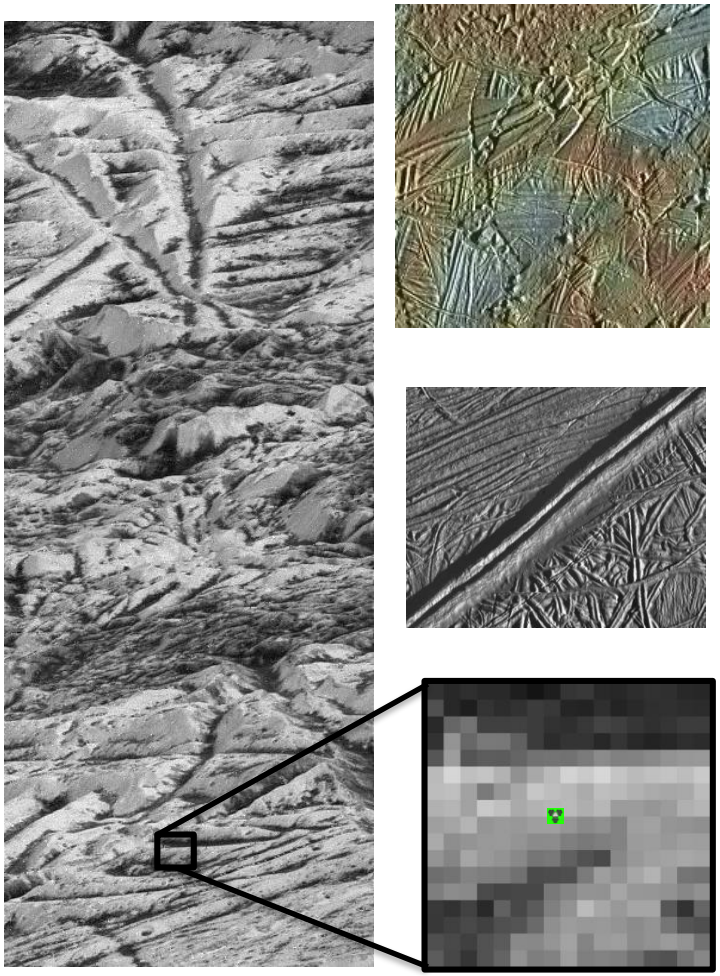
Challenging Surface Terrains

- Europa surface full of geometric features: chaos terrain, impact craters, ringed basins, ridges, cliff, etc.
- Highest resolution picture of Europa from the Galileo mission ~6 m/ pixel
- Terrain knowledge of Europa is limited now and would be unchanged at launch
  - *Updated terrain knowledge would be available en route to Europa*



http://photojournal.jpl.nasa.gov/catalog/PIA01180

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Smooth Area in the Icy World

- Smooth surface on the satellite image could be rough surface on human/lander Scale
- highly unlikely to find smooth areas at sub-meter scales
- Design a lander that could land in extremely rough terrain and still make relevant measurements

Devil's Golf (0.3m reliefs)

https://en.wikipedia.org/wiki/Devil's_Golf_Course

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Mechanics: Safe Velocity Determination

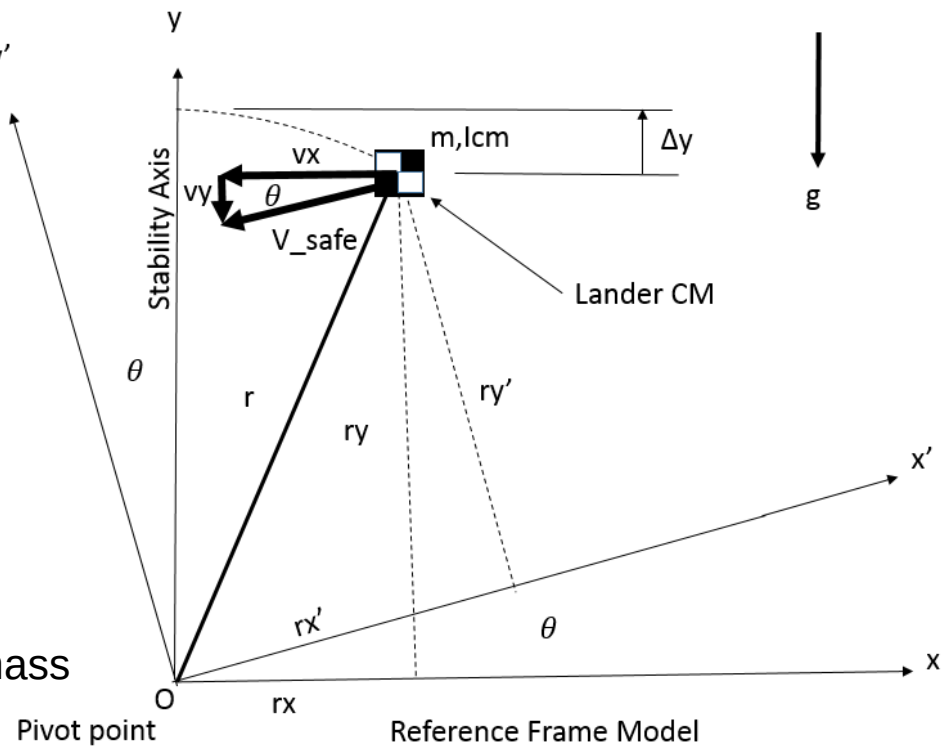
- V_{safe} is a measure of robustness of a lander to tip over and should be maximized
- V_{safe} highly dependent on lander geometry and mass distribution:

$$V_{safe} = \frac{1}{mry'}\sqrt{2mg\Delta y I_o}$$

Minimize ry' for larger V_{safe}

Maximize potential by maximizing Δy

Maximize mass distribution

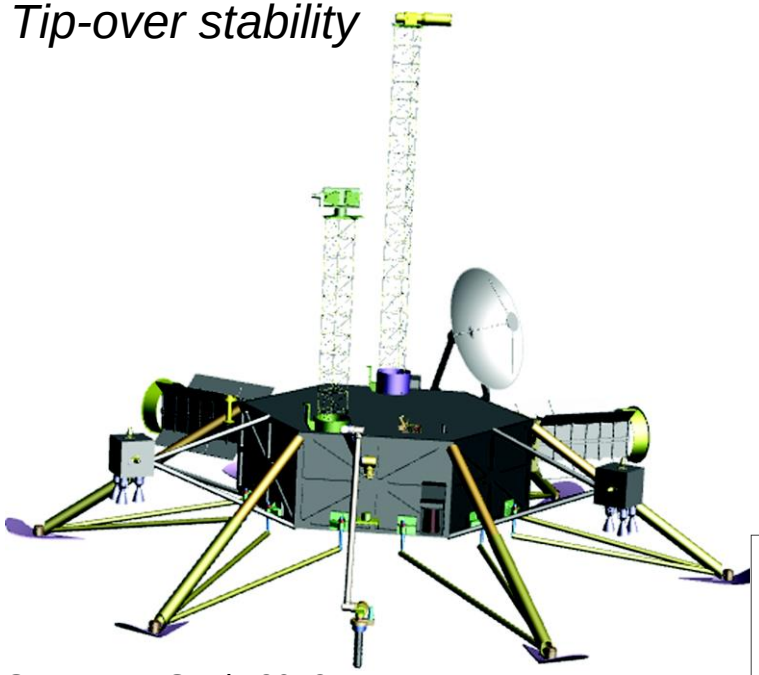


To maximize V_{safe} → **Minimize CM height, Maximize Footprint** → **Fix-Leg Pallet Lander**

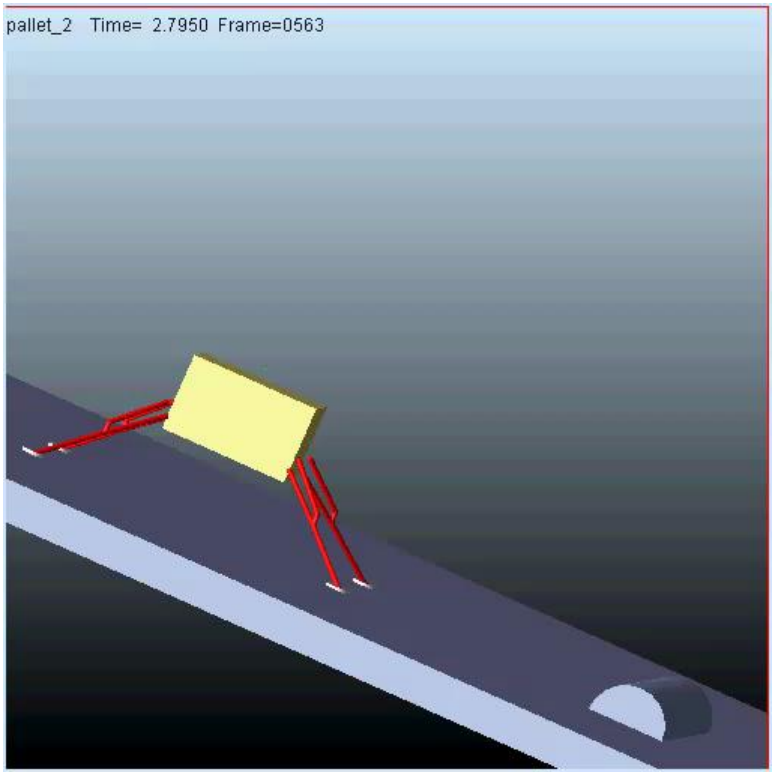
Lander Concept Evolution

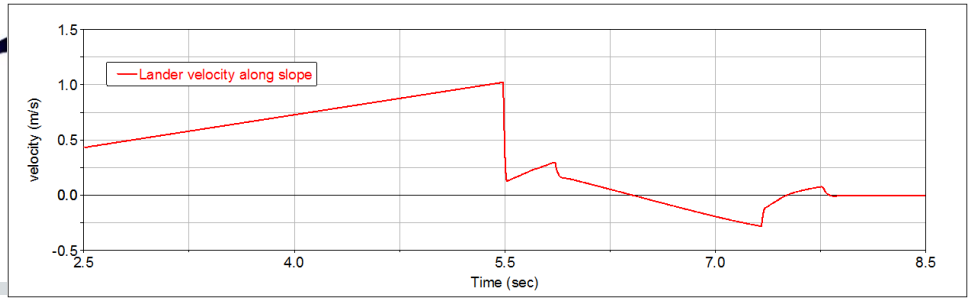
Fix-Leg Pallet Lander

- "Pallet" lander
  - *Wide base area*
  - *Low center of gravity*
  - *Tip-over stability*



NASA Europa Study 2012 Report
Europa Lander Artist's concept
by Europa Study Team, 2012.





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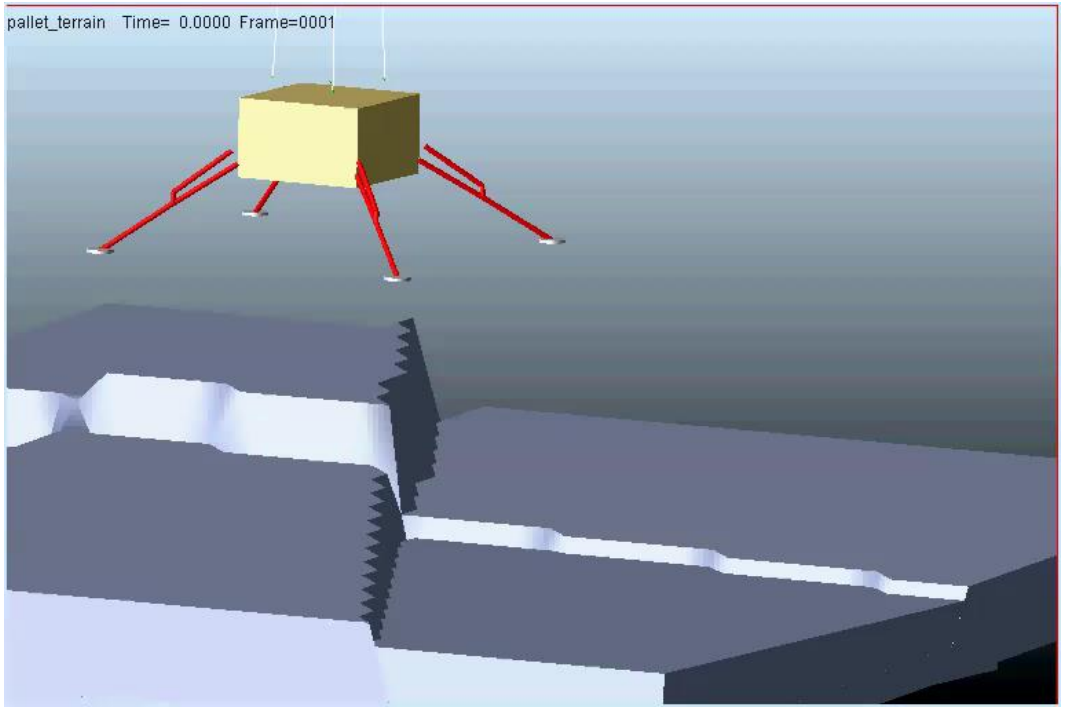
Pallet Lander Concept on Challenging Terrain

Adaptability is Critical

- Lander design for challenging terrain
  - *Need to accommodate large terrain variation such as slope and relief*
  - *Maintain a leveled pose after landing*
  - *Maintain a stable position for sampling operations*



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Europa Lander Concept- Deorbit, Descent, and Landing

Notional Powered Descent Landing with Sky Crane

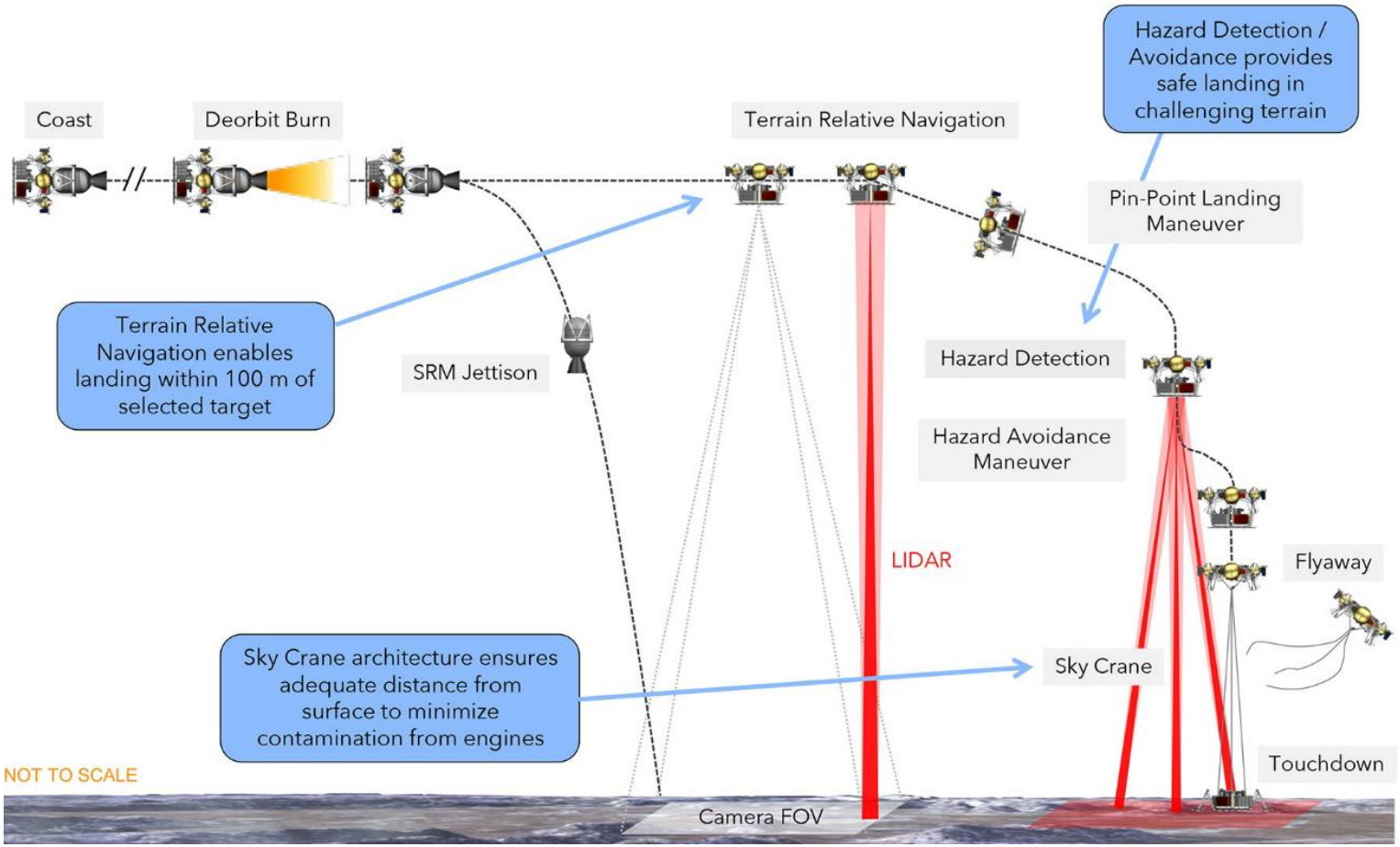
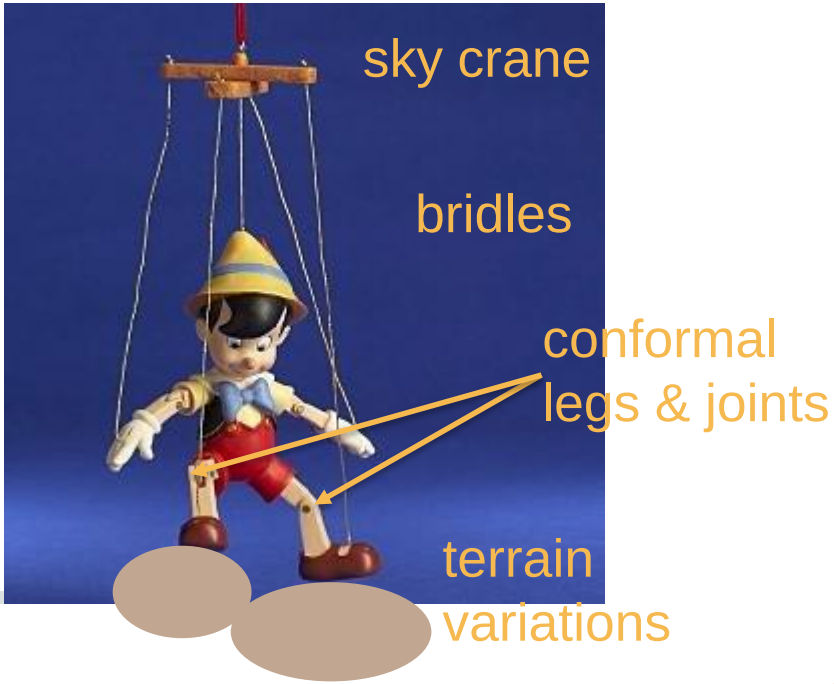


Fig 10.6: NASA Europa Study 2016 Report
Europa Lander Mission Concept

Compliant-Leg Lander Concept

- MSL-derived Sky Crane system to lower the lander to the surface via tethered bridles
- Stabilizer legs consist of joints - conformal legs to adapt to unknown terrain as the Lander slowly descends
- Stabilizer legs locked in position to yield a stable lander configuration for science operation



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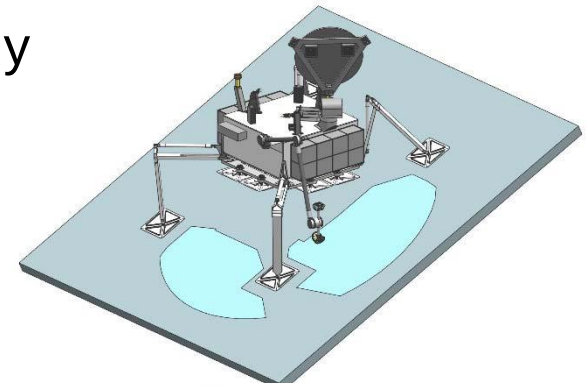
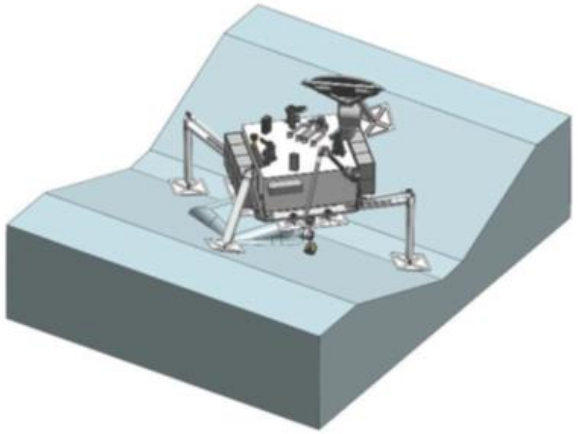
Lander Spacecraft Conceptual Design

- Stabilizer legs can individually extend, conforming to local terrain feature to achieve a level lander body in a wide range of surface topographies
  - *Would enable landing and sampling in a variety of terrains*





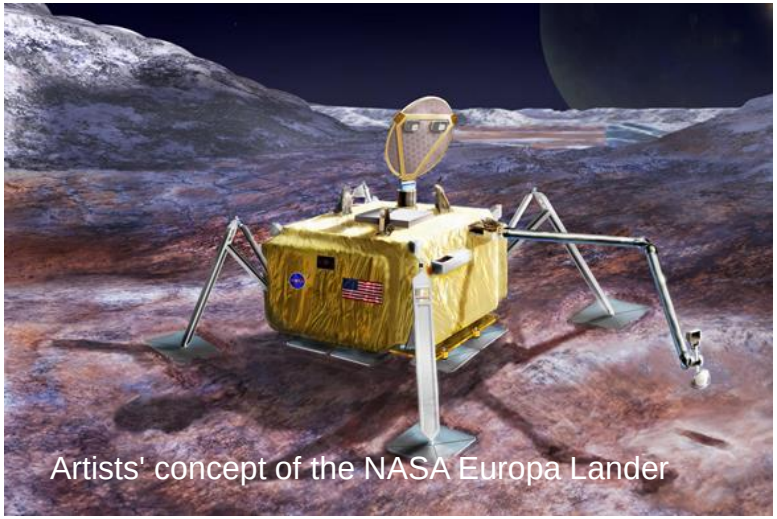


Fig 10.3:
NASA Europa Study 2016 Report
Europa Lander Mission Concept

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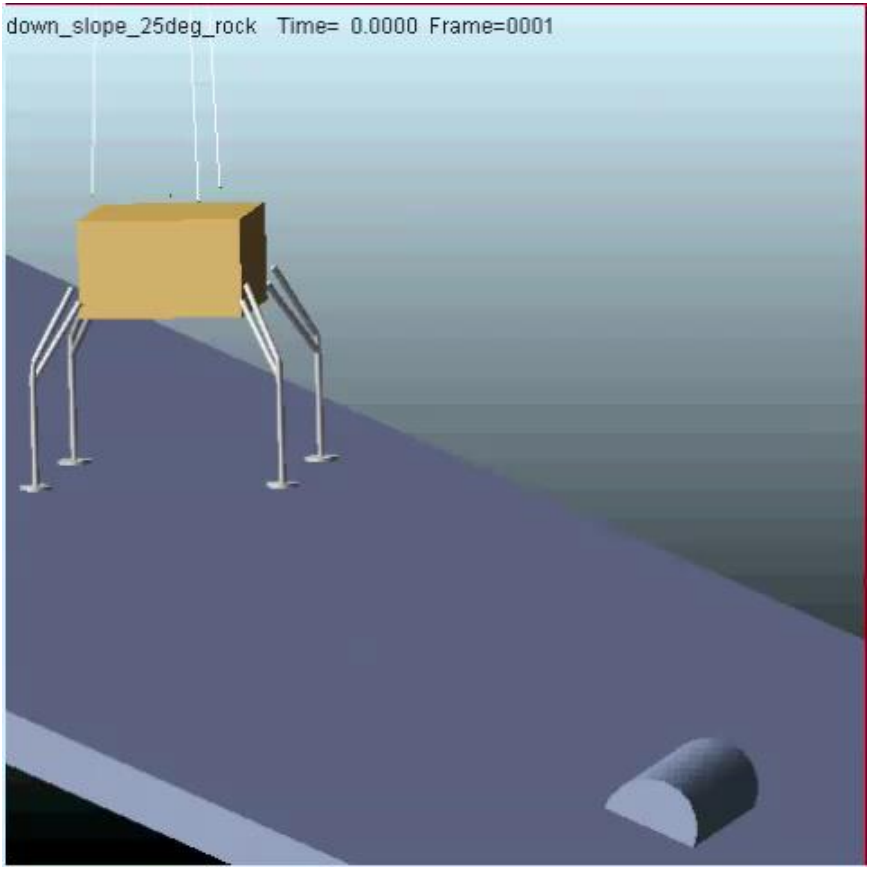
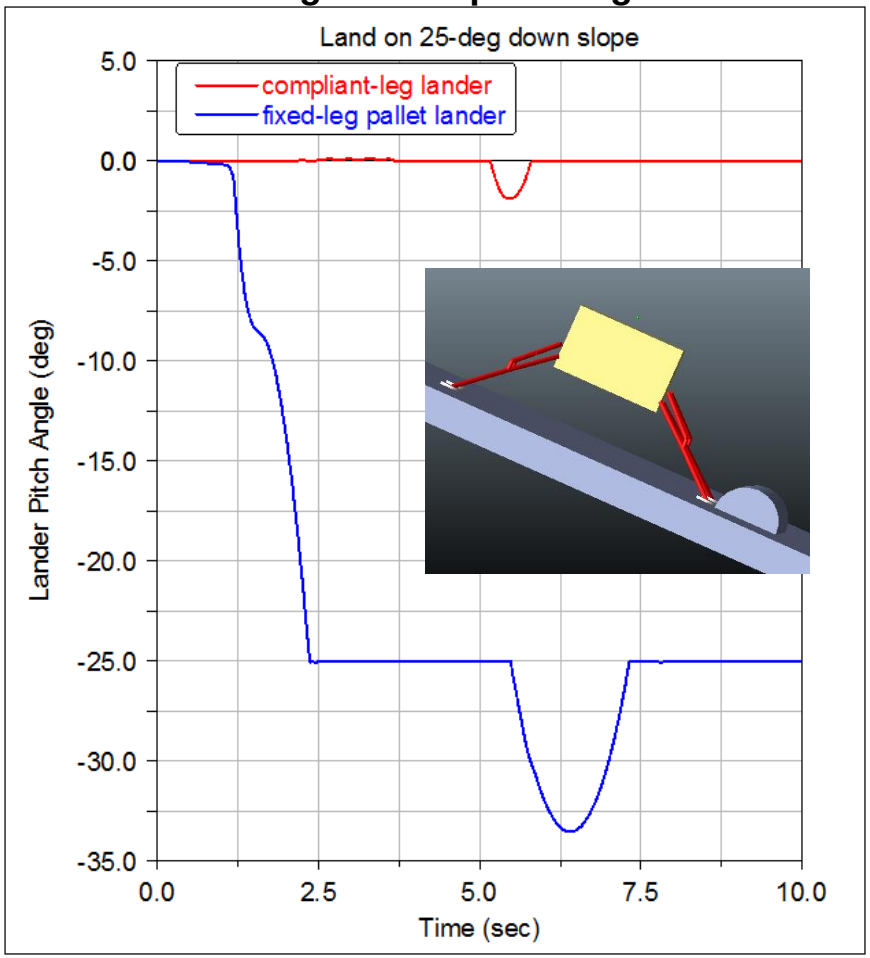
Case Study: Compliant Leg Lander

Land on 25-deg down Slope with Hard Stop



Fixed-leg vs. compliant leg Lander



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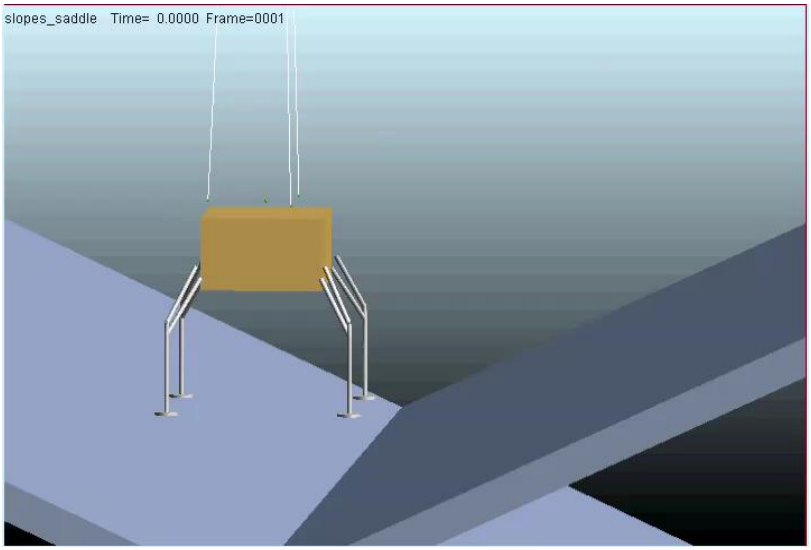
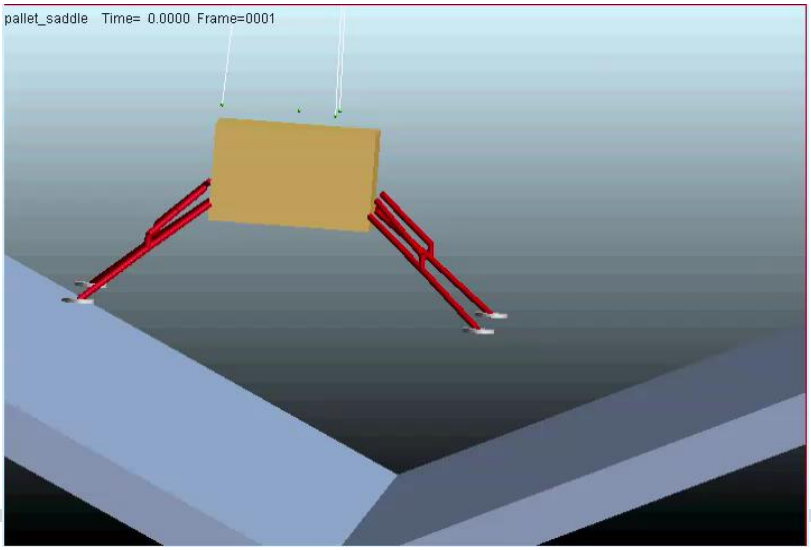
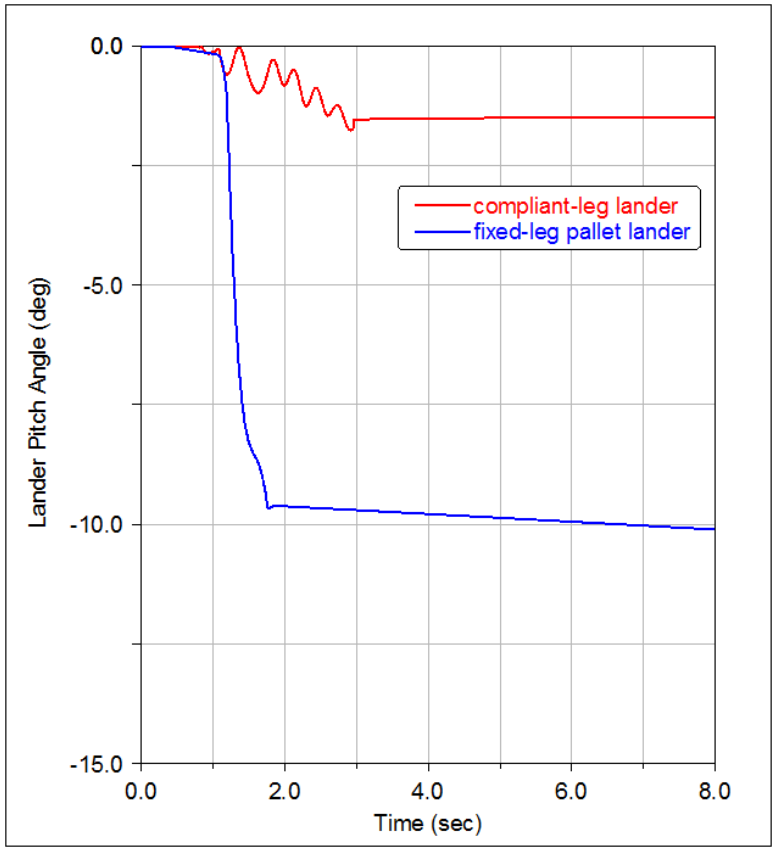
Case Study: Compliant-Leg vs. Fixed Leg Lander

Land on Sloped Relief





Fixed-leg vs. compliant leg Lander



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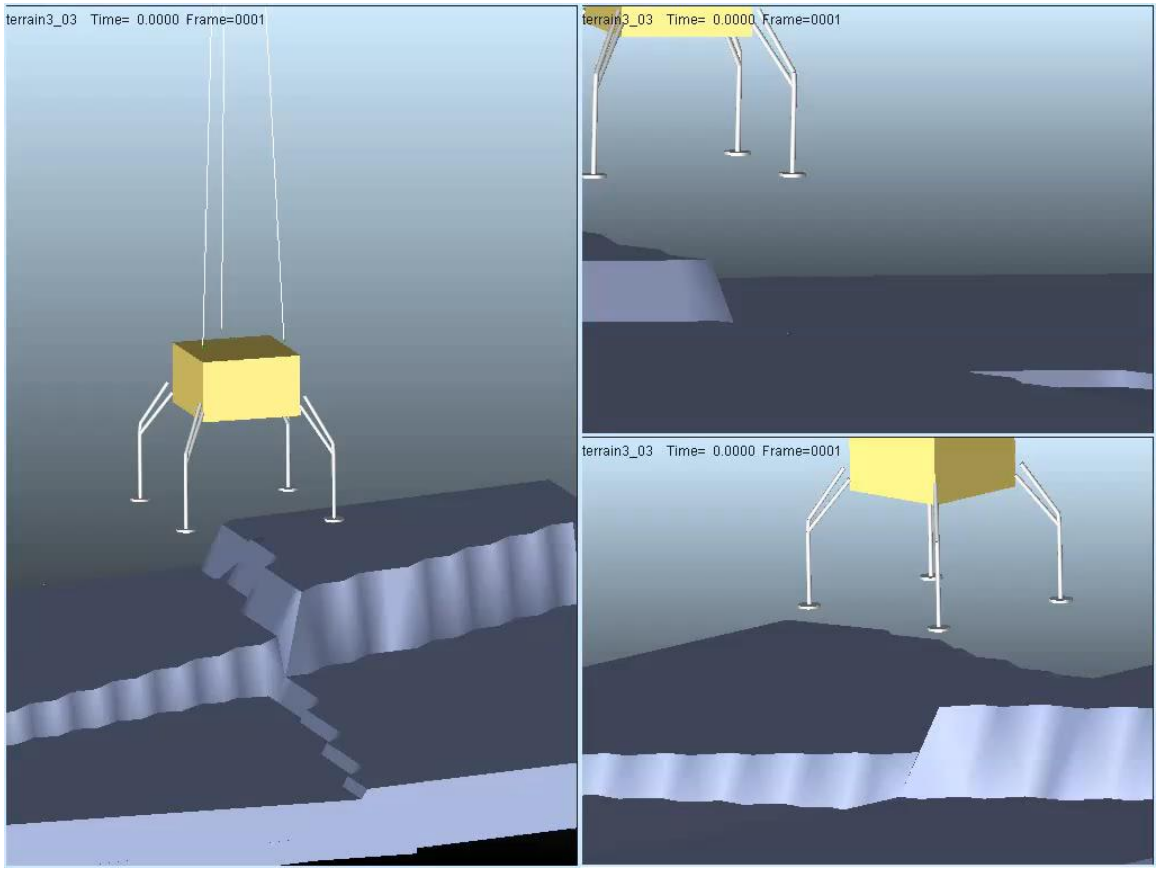
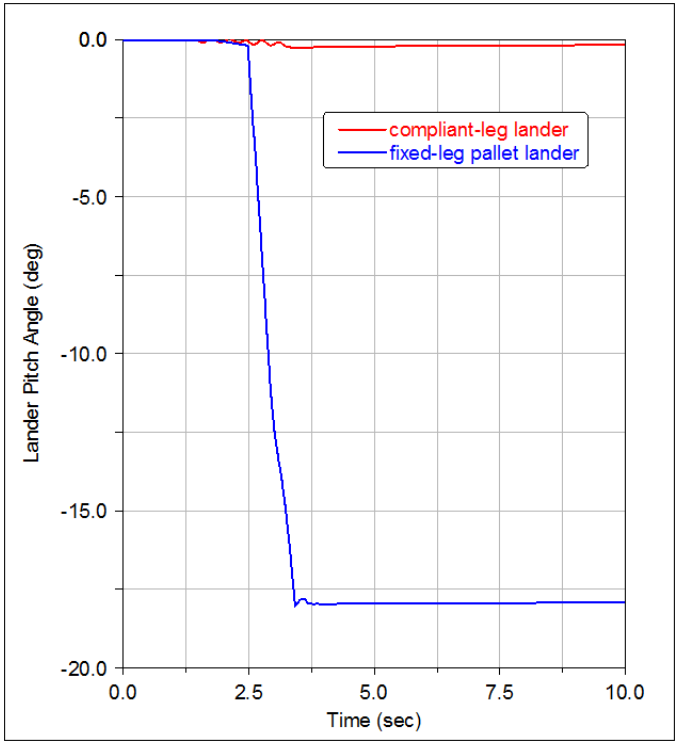
Case Study: Compliant Leg Lander





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Summary

Fixed-Leg vs. Compliant-Leg Landers Concepts

- Conventional fixed-leg lander is an economical solution and can provide tip-over stability
  - *Wide base area; Low center of gravity*
  - *May not be suitable for challenging terrains*
- Compliant-leg lander can accommodate large terrain variations
  - *Require powered descent landing with sky crane to maintain lateral coupling*
  - *Require choreographed timing sequences of legs locked in position to yield a stable lander configuration*

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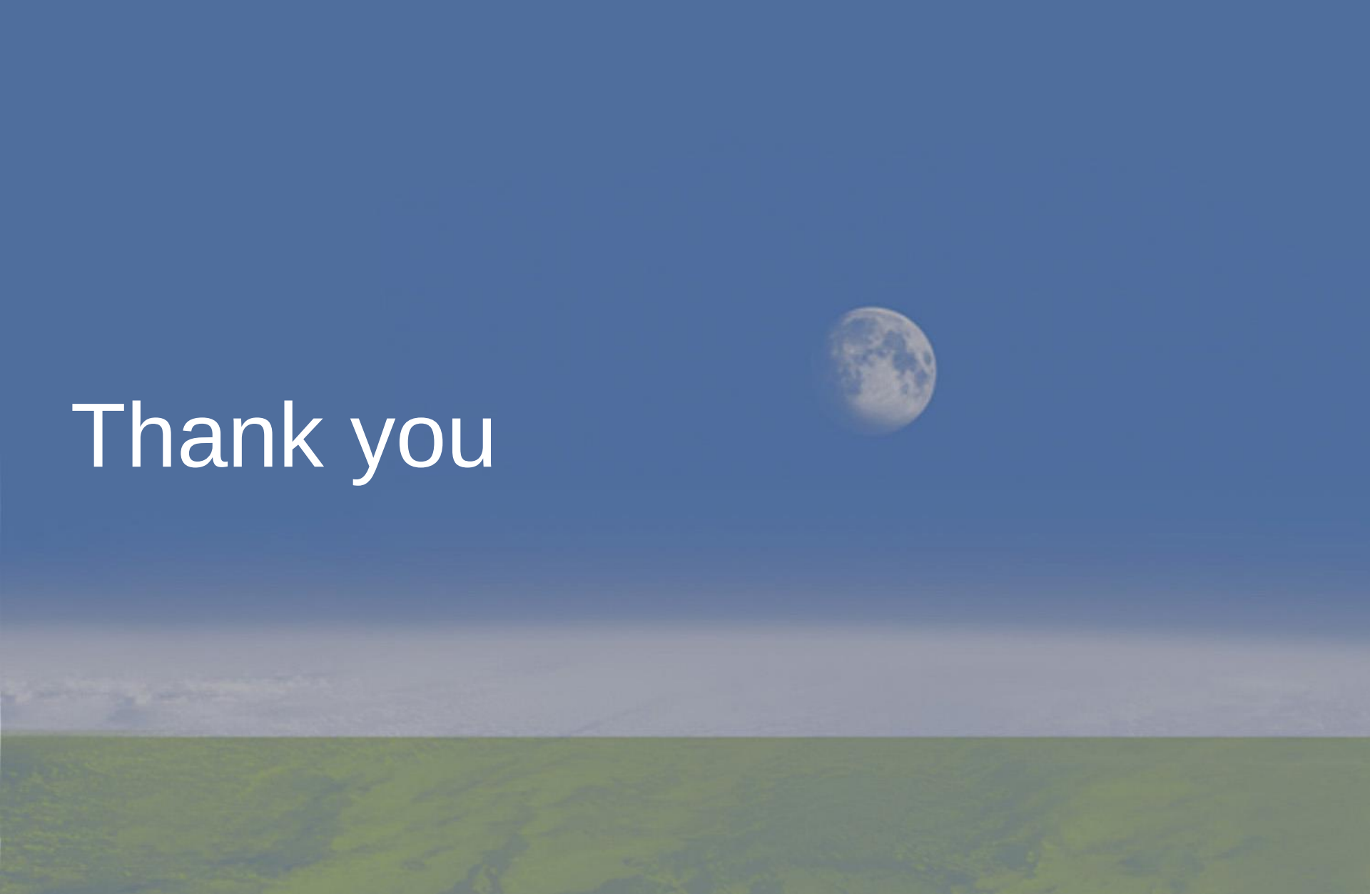
Thank you